

Short communication. Resistance to *Phytophthora infestans* in populations of wild potato species in the Sorata microcentre of genetic diversity, La Paz, Bolivia

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Abstract

Endemic wild potato species can be found in the Sorata microcentre of potato genetic diversity (Bolivia). This area, which lies at some 2640 m above sea level, is also a region of intensive *phureja* potato cultivation. Pressure from the fungus *Phytophthora infestans* is high. *In vitro* experiments were performed to assess the resistance of the following potatoes to *P. infestans*: i) populations of the wild species *Solanum acaule* (*S. acl*), *S. circaefolium* (*S. crc*-LA, *S. crc*-LB and *S. crc*-CO) and *S. achacachense* (*S. ach*), maintained at the Belén Research Station *ex situ* bank, ii) the reference species *S. capsicibaccatum* (*S. cap*), *S. berthaultii* (*S. ber*), *S. toralapanum* (*S. tor*) and *S. sparsipilum* (*S. spl*), and iii) susceptible cultivated varieties of *S. phureja* (*S. phu*) and *S. tuberosum* subsp. *andigena* (*S. adg*). The populations of *S. acl*, *S. crc*-LA, *S. crc*-LB and *S. crc*-CO showed high levels of resistance to *P. infestans*, while *S. ach* was very susceptible, in fact even more so than *S. phu*. *S. tor* was very resistant, while *S. cap*, *S. ber* and *S. spl* showed susceptibility similar to that of *S. phu*. The susceptible control *S. adg* showed the expected response to *P. infestans*, while that of *S. phu* was in agreement with its non-specific resistance to this pathogen.

Additional key words: late blight, non-specific resistance.

Resumen

Resistencia a *Phytophthora infestans* de poblaciones de especies silvestres de papa del microcentro de diversidad genética Sorata, La Paz, Bolivia

En el microcentro de diversidad de papas Sorata, Bolivia, situado a 2640 metros sobre el nivel del mar, algunas especies silvestres tienen distribución endémica, el cultivo de papas *phureja* es intensivo y hay alta presión de *Phytophthora infestans*. Por su resistencia a este hongo, se evaluaron *in vitro*: i) poblaciones de especies silvestres de *Solanum acaule* (*S. acl*), *S. circaefolium* (*S. crc*-LA, *S. crc*-LB y *S. crc*-CO) y *S. achacachense* (*S. ach*), conservadas en el Banco *ex situ* de la Estación Experimental Belén; ii) *S. capsicibaccatum* (*S. cap*), *S. berthaultii* (*S. ber*), *S. toralapanum* (*S. tor*) y *S. sparsipilum* (*S. spl*), especies de referencia, y iii) variedades cultivadas susceptibles de *S. phureja* (*S. phu*) y *S. tuberosum* subsp. *andigena* (*S. adg*). Las poblaciones de *S. acl*, *S. crc*-LA, *S. crc*-LB y *S. crc*-CO mostraron un alto grado de resistencia a *P. infestans*. En cambio, *S. ach* mostró un alto grado de susceptibilidad, incluso superior a *S. phu*. Las poblaciones de *S. tor* mostraron alto grado de resistencia, y *S. cap*, *S. ber* y *S. spl* niveles similares de susceptibilidad a *S. phu*. El testigo susceptible *S. adg* mostró la esperada susceptibilidad a *P. infestans*, y *S. phu* fue concordante con su resistencia no específica al patógeno.

Palabras clave adicionales: resistencia no específica, tizón tardío.

In the Department of La Paz, in eastern Bolivia, potato (*Solanum tuberosum* L.) cultivation is concentrated on the *Altiplano* (the High Plain) and in

mountainous areas between altitudes of 3820 and 4500 m. The *Prepuna* (a High Andes ecosystem) and valley areas under 3200 m form another, traditional, and relatively important, growing area. These microregions fall within the Larecaja, Camacho, Muñecas, Bautista Saavedra, Nor Yungas and Sur Yungas provinces. Given the climate of these areas, cultivation is seriously

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affected by late blight caused by *Phytophthora infestans* Mont de Bary. The disease it causes is known to growers as *Llejte* (an Aymara word meaning 'burnt'). It is mainly controlled with fungicides, and in some regions by sowing at specific times. The Department of La Paz is the main centre of diversity for wild potato species in Bolivia (Ochoa, 1990). The great majority of wild species reported for the region are found in wet and temperate areas where the incidence of *P. infestans* is high. In some microcentres of diversity, such as Sorata (Province of Larecaja), some species such as *S. circaeifolium*, *S. achacachense* and *S. candolleianum* are widely distributed and late blight (*P. infestans*) is a limiting factor in potato production. Recently, *P. infestans* has been reported affecting certain wild species in *in situ* conditions (Coca-Morante, 2003).

Attempts to improve potato *r* genes have led to the study of wild and other cultivated species, and several important advances in achieving resistance to *P. infestans* have been made (Hawkes and Hjerting, 1989; Ruiz de Galarreta *et al.*, 1998). Currently, *r* genes from *S. tuberosum* subsp. *andigena*, *S. phureja*, as well as certain wild species, are helping to improve this resistance. In Bolivia, *P. infestans* is endemic over the distribution ranges of wild potato species. The survival of the latter suggests they possess resistance mechanisms, or that a process of gradual genetic erosion is underway. Being a primary centre of potato genetic diversity, the variability of *P. infestans* may be ample, and different resistance mechanisms may have evolved.

The aim of the present work was to determine the *in vitro* resistance to isolates of *P. infestans* of populations of wild potato species from the Sorata microcentre of diversity.

Different populations of wild potato species were selected (Fig. 1, Table 1) from the Belén Research Station *ex situ* bank (Faculty of Agriculture, Universidad Mayor de San Andrés) (see Coca-Morante, 2003). Small tubers belonging to the chosen species were sown under glass, along with locally cultivated susceptible controls (Table 1). All tubers were sown in plastic pots (15 × 10 cm) containing a mixture of sterilised substrate, black soil and fine sand (1:2:1). All treatments were replicated five times.

P. infestans isolates were collected from leaflets of the *phureja*s potato variety *S. phureja* Juxepczuk et Bukasov growing in the Sorata area. These isolates

were maintained on potato (*Solanum tuberosum* subsp. *andigena* var. Waych'a Paceña) slices at 18°C until inoculating the leaflets of the test plants (three replicates per treatment) using the method described by the International Potato Center (CIP, 2001). These leaflets (all taken from the middle part of the plant before flowering) were moistened with sterile water and placed in Petri dishes containing 2% agar water. All inoculations were made using isolate CH-001. Twenty microlitres of a suspension containing 8×10^3 sporangia filtered through 20 and 10 µm sieves were placed on the lower side of each leaflet. The inoculated leaflets were then maintained in the Petri dishes at 18°C. The affected area (disease severity) and sporulation were recorded from 48 h to 120 h using a binocular microscope. The mean disease severity values were used to determine the area under the disease progress curve (AUDPC) according to the method of Campbell and Madden (1990):

$$AUDPC = \sum_i^{n-1} 4 (y_i + y_{i+1}) / 2 (t_{i+1} - t_i),$$

where *n* is the number of determinations (i.e., the number of disease severity readings), *y* is disease severity, and *t* is the time (in days) elapsed since inoculation. The mean AUDPC values at 120 h were analysed using a random block design.

Figure 2 shows that the populations of the wild species differ in their resistance to *P. infestans*. Those of the Megistacroloba (*S. tor*), Acaulia (*S. acl*) and Circaeifolia (*S. crc* and *S. cap*) series showed the lowest AUDPC values, the very lowest being those for the *S. tor* and *S. acl* populations. Although the *S. crc*-LA, *S. crc*-CO and *S. crc*-LB populations showed significant differences in their resistance to *P. infestans*, all had low AUDPC values. The *S. cap* population showed the highest AUDPC values of the Circaeifolia series, similar to other populations susceptible to *P. infestans*. The *S. ach* population showed AUDPC values higher than those of the *S. crc* populations, and similar to those of the *S. phu* control variety. The susceptible *phureja* (local) and Waych'a Paceña varieties also showed significantly different behaviour with respect to *P. infestans*.

The *S. acl* population from the high area of the Sorata microcentre (Chojchoni, 3500 m), showed the greatest resistance to *P. infestans*. Hawkes and Hjerting (1989) report this species to show characteristics of field resistance to *P. infestans*.

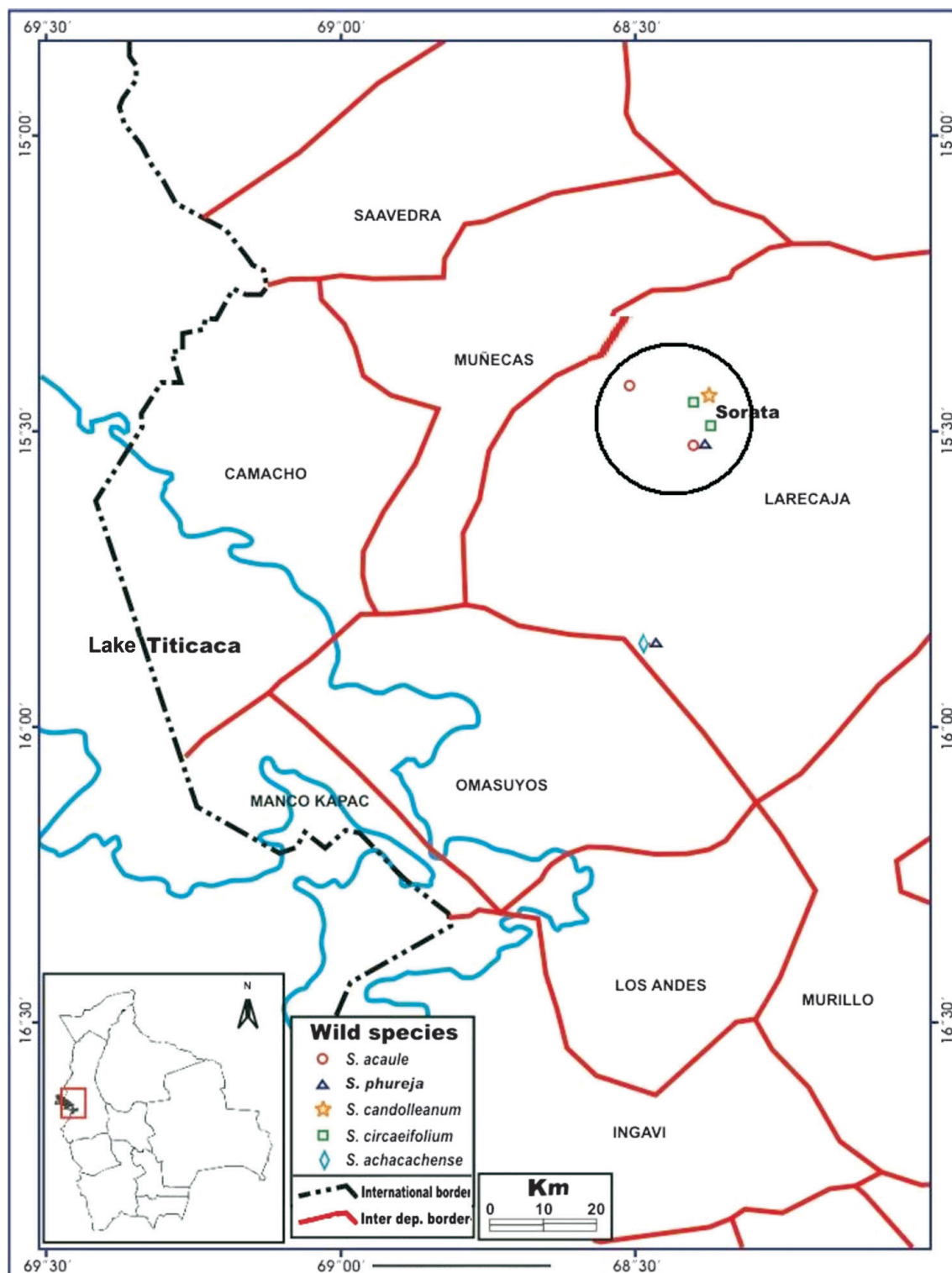


Figure 1. Distribution of wild potato species in the Sorata genetic diversity microcentre, La Paz (circle). Blue line: lake Titicaca border.

Table 1. Populations of wild potato in the Sorata diversity microcentre, La Paz, and control and cultivated species

Species of <i>Solanum</i>	Code	Type	Series	Origin ¹
<i>S. megistacrolobum</i> var. <i>toralapnaum</i> (Card. y Hawkes) Ochoa	tor	Control	Megistacroloba	Sayari, Cochabamba, 4250
<i>S. acaule</i> Bitter	acl	Wild	Acaulia	La Apacheta, La Paz, 4150
<i>S. circaefolium</i> Bitter	crc - LA ²	Wild	Circaeifolia	Laripata Alto, La Paz, 2650
<i>S. circaefolium</i> Bitter	crc - CO ²	Wild	Circaeifolia	Cotaña, La Paz, 2620
<i>S. circaefolium</i> Bitter	crc - LB ²	Wild	Circaeifolia	Laripata Bajo, La Paz, 2620
<i>S. circaefolium</i> var. <i>capsicibaccatum</i> Ochoa	cap	Control	Circaeifolia	Tunari, Cochabamba, 2750
<i>S. sparsipilum</i> (Bitter) Juz. et Bukasov	spl	Control	Tuberosa	Ajllata, La Paz, 3810
<i>S. achacachense</i> Cárdenas	ach	Wild	Tuberosa	La Apacheta, La Paz, 4150
<i>S. berthaultii</i> Hawkes	ber	Wild	Commersoniana	San Pedro, Cochabamba, 2650
<i>S. phureja</i> Juz et Bukasov var. <i>negra</i>	phu	Cultivated	Tuberosa	Umanata, La Paz, 3150
<i>S. tuberosum</i> subsp. <i>andigena</i> var. Waych'a Paceña	adg	Cultivated	Tuberosa	Belén, La Paz, 3810

¹ Locality, Department and altitude (m). ² LA, CO and LB, populations of *S. circaefolium* from different localities.

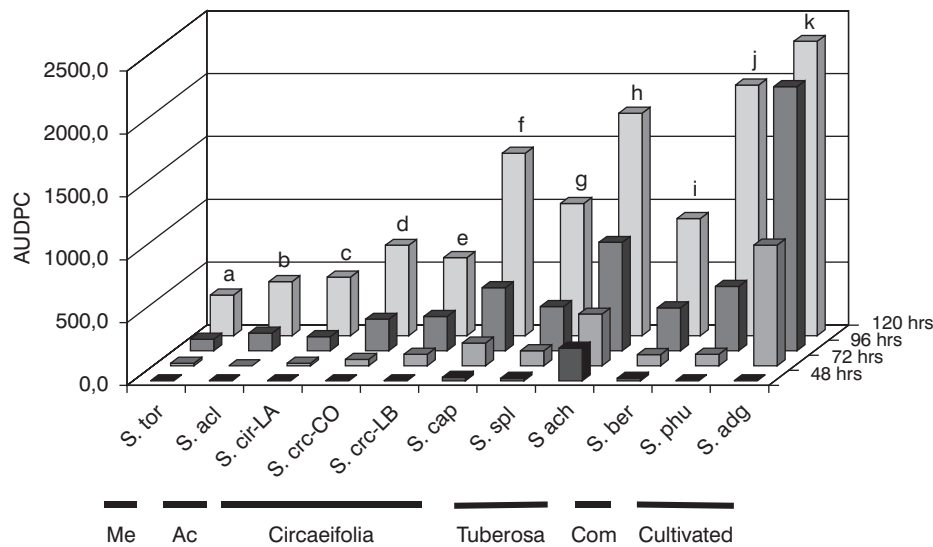


Figure 2. AUDPC for wild species and populations with respect to resistance to *P. infestans*. Me = Megistacroloba series; Ac = Acaulia series; Com = Commersoniana series. Significance set at $F_{.01}$.

The populations *S. crc*-LA, *S. crc*-LB and *S. crc*-CO also showed resistance, but with differences, even though they came from neighbouring areas. These results agree with other reports indicating that *S. crc* shows partial (and promising) resistance to *P. infestans* (Hawkes and Hjerting, 1989; Ruiz de Galarreta *et al.*, 1998). This is in line with the current situation in the Sorata microcentre where, even though potato

cultivation is intensive, and despite negative human activities, populations of *S. crc* survive in marginal sites through their resistance to the effects of *P. infestans*.

The population *S. ach* was very susceptible to *P. infestans*. This population, from the type locality of «La Apacheta» (3200-3500 m), between Achacachi (Omasuyos Province) and Sorata (Larecaja Province), is now found in an area of intensive *phurejas*

cultivation where *P. infestans* is endemic and has serious effects. In 2003 it was reported that *P. infestans* affected *S. ach* in *in situ* conditions (Coca Morante, 2003). Apparently, *P. infestans* may be acting as a negative selection factor, and appears to be having a certain impact on existing populations.

Differences in resistance to *P. infestans* were also seen in the populations of control wild species, with *S. tor* showing the highest levels. This population, which comes from high altitude areas (4250 m), was reported by Hawkes and Hjerting (1989) to show non-specific field resistance to *P. infestans*, while Ruiz de Galarreta *et al.* (1998) recorded it as susceptible. The *S. cap* population was highly susceptible compared to those of *S. crc* of the Sorata microdiversity centre. The *S. cap* population comes from the Cochabamba Valley (2750 m). Alandia (1951) reported *S. cap* to be resistant to the «D» race of *P. infestans* from this area. Later, Hawkes and Hjerting (1989) reported its high field resistance to *P. infestans*, and 11 years later its partial resistance to the same fungus was reported (Ruiz de Galarreta *et al.*, 1998). Apparently, *S. cap* is experiencing a process of erosion of its resistance to *P. infestans*, although it should also be remembered that different population of the pathogen may also vary.

The population *S. spl* is more resistant to *P. infestans* than *S. cap*. *S. spl* comes from the Lake Titicaca area (3820 m) (in the basin of which *P. infestans* has recently been detected in potatoes [Coca-Morante, 2003]) and has been reported to show non-specific resistance to *P. infestans* (Hawkes and Hjerting, 1989; Ruiz de Galarreta *et al.*, 1998).

The *S. ber* populations from the Cochabamba Valley showed a level of susceptibility similar to that of *S. spl*. Contradictory reports exist, however, regarding its response to *P. infestans*. Hawkes and Hjerting (1989) report it to show good field resistance, Ochoa (1990) indicate it to be very susceptible, Ruiz de Galarreta *et al.* (1998) indicate that it is partially resistant, and Trognitz *et al.* (1999) that it is highly resistant with respect to a specific race of *P. infestans*. The control varieties of red *phureja* (*S. phu*) and Waych'a Paceña (*S. adg*) showed susceptibility to *P. infestans*, although to a significantly different degree. The lower susceptibility of some *phurejas* varieties, attributed to the presence of additive genes, is reported by Trognitz *et al.* (1999) as high resistance (non-specific reaction). These varieties have been traditionally cultivated by

farmers despite the severity of *P. infestans* infestations, both in the Sorata microcentre and in other areas of Bolivia.

The difference in the responses of the wild populations in this work compared to those reported by other authors may be explained by variations in the different *P. infestans* populations. In Bolivia, A2 mating and clonal reproduction has been reported for *P. infestans* (Forbes *et al.*, 1998). However, the different *P. infestans* isolates affecting wild potato species have not yet been studied.

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